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Attitude towards risk, uncertainty, and fixed investment

Hong Bo[a], Elmer Sterken[b,*]

[a] *Department of Financial & Management Studies, SOAS, University of London, London, United Kingdom*
[b] *Department of Economics, University of Groningen, P.O. Box 800, 9700 AV Groningen, The Netherlands*

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Abstract

We explore the relevance of the risk attitude of managers to the investment-uncertainty relation. Higher moments of the distribution of net profits are used to measure the risk premium of the firm, from which we derive a proxy for the risk aversion of managers. Using an unbalanced panel of Dutch listed firms, we find that in general a low degree of risk aversion coincides with a positive impact of demand uncertainty on investment. More specifically, we find that risk-averse firms respond to demand uncertainty by cutting investment, while the investment undertaken by risk-taking firms responds to demand uncertainty positively.

JEL classification: E2; G3

Keywords: Risk attitude; Uncertainty; Fixed investment

1. Introduction

The effect of uncertainty on investment is a prominent topic in investment studies. The literature has identified several channels through which uncertainty can affect investment: (1) the risk attitude of decision-makers (Nakamura, 1999; Nickell, 1978; Zeira, 1990); (2) the shape of the marginal product of capital (Abel, 1983; Caballero, 1991; Hartman, 1972); (3) substitutability of production factors (Hartman, 1976; Leahy & Whited, 1996); (4) irreversibility and the option value of waiting (Dixit & Pindyck, 1994); and (5) financial constraints (Minton & Schrand, 1999). Much effort has focused on testing the impact of channels (2)–(5) on investment. However, the results are not conclusive.

* Corresponding author. Tel.: +31 50 3633723; fax: +31 50 3637337.
E-mail address: e.sterken@rug.nl (E. Sterken).

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First, it is not clear whether uncertainty discourages or encourages investment. Different theoretical approaches propose different conclusions. Second, although most studies find the negative effect of uncertainty on investment, it is not clear through which channel uncertainty affects investment.[1] From an empirical point of view, it is hard to identify each channel separately. Almost all empirical research on the effect of uncertainty on investment ignores a fundamental factor in the objective function of the firm: the risk attitude of managers. Most empirical studies assume that managers of the firm are risk neutral when they make investment decisions.

In reality, however, managers are more likely to be risk-averse. When agency costs between managers and shareholders are absent, managers represent shareholders and the objective function of managers is to maximize shareholders' value. Nickell (1978) argues that only under the assumptions of perfect capital markets and certainty, can one ignore the preferences of the firm's shareholders in considering the firm's decisions. Therefore, under uncertainty shareholders' consumption behavior and their preference structure become important. In this case, the objective function of the firm should be derived from the intertemporal optimization problem of the owners (consumers) of the firm. When agency costs of management are high, the firm's objective function is to maximize the utility of managers. Although protected by limited liability laws in many countries, managers are trying to avoid bankruptcy since they do not want to lose their private benefits of control. Although it facilitates the analysis, the assumption of risk-neutrality is not realistic. This suggests that we should treat firms as agents who are maximizing the expected discounted *utility* of profits rather than maximizing discounted profits.

The consequences of ignoring non-neutral risk attitudes of managers in investment studies can be severe. First, attitude towards risk, reflected in the utility function of the investment decision makers, is a prominent determinant of the investment-uncertainty relation. Second, neglecting attitude towards risk messes up the impact of other important factors predicting the effect of uncertainty on investment. For example, many authors, after assuming risk neutrality and obtaining a negative sign of uncertainty in investment equations, conclude that irreversibility induces the negative effect of uncertainty on investment.[2] However, since a higher degree of risk aversion is likely to generate a negative impact of uncertainty on investment, one could argue that it might be the risk aversion attitudes of managers of the firm rather than irreversibility that induces the negative effect. Defining separate empirical indicators of risk aversion and irreversibility would be a requisite to identify both channels. Gollier (2000) finds that the degree of risk aversion of agents increases with financial constraints. According to Gollier capital market imperfections may discourage investment not only because of limited access to external finance but more directly because they discourage individuals' willingness to bear risk. Therefore, if the impact of risk attitude could be isolated and controlled, the estimated impact of other factors, like irreversibility, could be purified and made more informative.

The debates and mixed evidence in the literature on the investment-uncertainty relationship suggest that we should go back to the risk attitude of managers to investigate firm investment behavior under uncertainty. Caballero (1991) argues that "the relationship between changes in price uncertainty and capital investment under risk neutrality is not robust. . .it is very likely that

[1] For a review of the empirical research on the investment-uncertainty relationship, see Chapter 6, Lensink, Bo, and Sterken (2001).

[2] Among 20 empirical studies surveyed by Lensink et al. (2001), 17 papers find a negative effect of uncertainty on investment, 11 of these 17 papers explain the negative effect of uncertainty by explicitly referring to the irreversibility hypothesis.

it will be necessary to turn back to risk aversion, incomplete markets and lack of diversification to obtain a sturdier negative relationship between investment and uncertainty."

Although theories predict that the risk attitude of managers influences the optimal output and investment decisions of the firm under uncertainty (see the related literature in Section 2 of this paper), the evidence in the literature is scant. One important obstacle is that empirical proxies for the risk attitude of managers are not directly available. The contribution of this paper is to derive an empirical proxy for the risk attitude of managers based on observed net returns data, which enables us to test how risk attitude changes the effect of uncertainty on investment. To the best of our knowledge, this paper is the first attempt to empirically analyze the impact of risk attitudes of managers on the investment-uncertainty relationship.

Two issues remain largely unresolved. First, as in all other studies on the investment-uncertainty relationship, it is hard to quantify the exact impact of any type of uncertainty on investment. Theoretical and empirical studies focus on the sign of the relation and not on the magnitude of the impact. Second, it is hard to establish whether the risk attitude assumption complements or substitutes for other determinants of the investment-uncertainty relationship, because all explanations interact. We show that abandoning the assumption of risk neutrality gives another channel for the impact of uncertainty on investment. It remains an empirical quest, though, whether or not assuming risk neutrality interferes with other channels. We do not solve this issue, but merely explore the new role of the managerial risk attitude and leave the assessment of its relative impact to future studies.

The rest of the paper is organized as follows. Section 2 briefly reviews the related literature from which we draw an analytical model justifying why risk attitude should be important for the investment decision of the firm under demand uncertainty. In Section 3, we describe the construction of the empirical proxy for the risk attitude of managers. Here we first follow Fisher and Hall (1969) to construct the risk premium of the firm. Then we derive the measure of risk aversion for the managers of the firm based on the relation between the risk premium and the measure of risk aversion predicted by utility theory (e.g., Arrow, 1971). Section 4 describes the data and the measurement of demand uncertainty. Section 5 presents the results obtained by the system Generalized Method of Moments (GMM) estimator. Section 6 summarizes and concludes the paper.

2. A theoretical model of risk attitude and the investment-uncertainty relationship

2.1. Related literature

Risk attitude has been theoretically identified as one important factor that affects firm behavior. Sandmo (1971, p. 65) explicitly criticizes the assumption that the firm is risk-neutral. He proves that risk aversion reduces the optimal production decision of a competitive firm under output price uncertainty. Leland (1972) extends the Sandmo (1971) perfectly competitive model to imperfectly competitive quantity- and price-setting firms. He shows that risk aversion leads to lower optimal output for the quantity-setting firm, and a lower quantity and price when the firm sets both before the uncertain demand is revealed, although the impact of risk aversion on a price-setting firm is ambiguous. Hartman (1976) theoretically proves that the effect of output-price uncertainty on capital inputs depends on the substitutability between capital and labor. Moreover, he claims that risk aversion influences the way the firm adjusts capital input in response to output-price uncertainty, although the direction of the impact of risk aversion is ambiguous. Nickell (1978, p. 75) provides a model in which he compares the output decision of a competitive firm under demand uncertainty between risk neutrality and risk aversion. He concludes that when demand levels are uncertain, risk-averse behavior is bound to lower capacity levels and the optimal capacity level is a declining function of the degree of risk aversion. Zeira (1990) analyzes the effect of wage rate uncertainty on the capital share using a general equilibrium framework. The degree of relative risk aversion is found to change the impact of uncertainty on investment. Nakamura (1999) explicitly models the risk-attitude parameter in the optimal investment rule. He derives an optimal investment rule that is a function of output-price uncertainty, the degree of relative risk aversion, and an elasticity of output to labor in the Cobb-Douglas production function. The effect of uncertainty on investment is shown to be positive, zero, and negative, depending on the trade-off between the degree of relative risk aversion and the elasticity of output to labor in the Cobb-Douglas production function.

2.2. The model

We derive a model of risk attitude and firm investment under demand uncertainty. The model is based on the framework of Sandmo (1970, 1971). We adapt the framework to the fixed investment decision of the firm. The aim of deriving the model is to show why and how risk attitude affects the impact of demand uncertainty on investment.

We start with a standard investment problem with no uncertainty. At time t the firm chooses the amount of investment. Assuming a one-year time-to-build lag of investment, the year t investment, I_t, will be used in production in the year $(t+1)$. Assuming that labor input is completely flexible, the firm adjusts its capital inputs in order to maximize the expected utility of profit in the year $(t+1)$. The profit function in the year $(t+1)$ is:

$$\pi_{t+1}(I_t) = F(K_{t+1}, L_{t+1}) - w_{t+1}L_{t+1} - G(I_t, K_t) - I_t, \tag{1}$$

where π_{t+1} is net operating profits for the period $(t+1)$, $F(K_{t+1}, L_{t+1})$ is the revenue function, K_{t+1}, L_{t+1} are the beginning-of-period capital stock and the labor input, I_t is the gross investment of the firm at time t, w_{t+1} is the nominal wage rate in the period $(t+1)$, and $G(I_t, K_t)$ is the internal convex cost function of adjusting the capital stock. Notice that in the profit function (1) we normalize the prices of output and capital goods to the unit for simplicity, although relaxing this assumption does not affect the conclusion of the model. Since we model the short-run investment decision, it is assumed that there is no depreciation of the capital stock from year t to the year $(t+1)$; this implies that $K_{t+1} = K_t + I_t$, i.e., the capital stock at the beginning of the year $(t+1)$ is the sum of the capital stock at the beginning of year t and investment implemented in year t. Therefore, the profit function (1) is reduced to:

$$\pi_{t+1}(I_t) = F((K_t + I_t), L_{t+1}) - w_{t+1}L_{t+1} - G(I_t) - I_t. \tag{2}$$

Taking into account the risk attitude of the managers of the firm, the objective function of the firm is to maximize the expected utility of the year $(t+1)$ profit:

$$\text{Max } E[U(\pi_{t+1})] = \text{Max } E\{U[F((K_t + I_t), L_{t+1}) - w_{t+1}L_{t+1} - G(I_t) - I_t]\}. \tag{3}$$

The first-order condition for investment is:

$$\frac{\partial E[U(\pi_{t+1})]}{\partial I_t} = E[U'(\pi_{t+1})(F_{I_t} - G_{I_t} - 1)] = 0. \tag{4}$$

The first-order condition (4) implies that at optimality the marginal revenue of investment equals the marginal cost of investment, i.e., $F_{I_t} = (G_{I_t} + 1)$. The second-order condition is:

$$\frac{\partial E[U(\pi_{t+1})]^2}{\partial I_t^2} = E[U''(\pi_{t+1})(F_{I_t} - G_{I_t} - 1)^2 + U'(\pi_{t+1})(F_{I_t I_t} - G_{I_t I_t})] = H. \tag{5}$$

We assume $H<0$ to ensure the existence of the maximized profit, which implies that we assume a concave marginal product of capital ($F_{I_t I_t} < 0$) and a convex adjustment cost function of capital ($G_{I_t I_t} > 0$). Notice that $H<0$ does not necessarily imply $U''(\pi_{t+1})<0$ (risk aversion), because in the optimal investment solution, $F_{I_t} = (G_{I_t} + 1)$, which allows $U''(\pi_{t+1})$ to have any sign. Therefore, the model applies to decision-makers who may be risk-averse, risk-neutral, or risk-taking. The first- and the second-order conditions (4) and (5) ensure the optimal investment policy when there is no uncertainty. Below we introduce uncertainty into the model. We first characterize uncertainty, then we investigate how uncertainty affects the optimal investment policy.

Assuming that the firm is facing demand uncertainty only, changes in the demand condition are reflected by changes in the revenue function. Following Sandmo (1970, 1971), we add two shift parameters, (γ, θ), to the revenue function $F(K, L)$, i.e., the revenue function under demand uncertainty is $(\gamma F + \theta)$. Further we assume that the stochastic demand can be characterized as a mean reversion process (e.g., Sandmo, 1970), which requires:

$$E[\gamma F + \theta] = 0, \tag{6}$$

Totally differentiating (6) gives: $(\mathrm{d}\theta/\mathrm{d}\gamma) = -E[F] = -\mu$, where μ is the mean of the revenue distribution. With demand uncertainty characterized by (6), the profit function (2) now becomes:

$$\pi_{t+1}(I_t, \gamma) = [\gamma F((K_t + I_t), L_{t+1}) + \theta] - w_{t+1}L_{t+1} - G(I_t) - I_t. \tag{7}$$

Now we can check the impact of demand uncertainty on the optimal investment policy. By totally differentiating the first-order condition for investment (4), and after implementing the stochastic shift $\gamma F + \theta$, with respect to the stochastic parameter γ:

$$\begin{aligned} E\Bigg[U''(\pi_{t+1})\left(\frac{\partial \pi_{t+1}}{\partial \gamma} + \frac{\partial \pi_{t+1}}{\partial I_t}\frac{\partial I_t}{\partial \gamma}\right)(F_{I_t} - G_{I_t} - 1) \\ + U'(\pi_{t+1})\left(F_{I_t I_t}\frac{\partial I_t}{\partial \gamma} - G_{I_t I_t}\frac{\partial I_t}{\partial \gamma}\right)\Bigg] = 0. \end{aligned} \tag{8}$$

Since $(\partial \pi_{t+1}/\partial \gamma) = F + (\mathrm{d}\theta/\mathrm{d}\gamma) = F - \mu$ and $(\partial \pi_{t+1}/\partial I_t) = F_t - G_{I_t} - 1$, from (8) we have:

$$\begin{aligned} &\frac{\partial I_t}{\partial \gamma} E[U''(\pi_{t+1})(F_t - G_{I_t} - 1)^2 + U'(\pi_{t+1})(F_{I_t I_t} - G_{I_t I_t})] \\ &\quad = -E[U''(\pi_{t+1})(F - \mu)(F_{I_t} - G_{I_t} - 1)]. \end{aligned} \tag{9}$$

Notice that the term $E[\ldots]$ on the left-hand side of (9) is the second-order condition (H); therefore:

$$\frac{\partial I_t}{\partial \gamma} = -\frac{1}{H} E[U''(\pi_{t+1})(F - \mu)(F_{I_t} - G_{I_t} - 1)]. \tag{10}$$

Rewriting (10) in terms of the Arrow-Pratt measure of absolute risk aversion $R_a = -(U''(\pi_{t+1})/U'(\pi_{t+1}))$, we obtain:

$$\frac{\partial I_t}{\partial \gamma} = \frac{1}{H} E[R_a U'(\pi_{t+1})(F-\mu)(F_{I_t} - G_{I_t} - 1)]. \tag{11}$$

Under uncertainty, $(F-\mu)$ and $(F_{I_t} - G_{I_t} - 1)$ change in the same direction, so that the product of the two terms is positive. We also know that $U'(\pi_{t+1}) > 0$ and $H < 0$; therefore, the sign of the impact of demand uncertainty on investment depends on the sign of the measure of absolute risk aversion R_a:

$$\frac{\partial I_t}{\partial \gamma} > 0,\ \frac{\partial I_t}{\partial \gamma} = 0,\ \text{ and }\ \frac{\partial I_t}{\partial \gamma} < 0\ \text{ if }\ R_a < 0\ \text{(risk-taking)},\quad R_a = 0\ \text{(risk-neutral)},$$
$$R_a > 0\ \text{(risk-averse)}.$$

The above model shows that the risk-attitude of the managers of the firm influences the impact of demand uncertainty on investment. The model provides a theoretical motivation to include the risk attitude parameter of managers in empirical investment equations. The next issue is how to construct an empirical proxy for the risk attitude of the managers of the firm.

3. Empirical proxy for the risk attitude of managers

One can use survey data to obtain a direct indicator of the risk attitude of the managers of the firm. For example, one may ask the managers to compare project A with certain returns (X) with project B with risky expected returns (Y). The managers may be asked to provide information on the returns they require if they choose to invest in project B. If the required expected returns of choosing the risky project is $\hat{Y}$, then the difference $(\hat{Y} - X)$ indicates the expected wealth the managers of the firm are prepared to forgo in order to change a risky choice into a certainty. Since the risk premium measures how much value the managers are willing to pay to convert an uncertainty choice into a certainty, the measure of risk attitude can be inferred from information on the risk premium. Although the use of survey data to derive risk attitude parameter for managers is scant in the literature on firm behavior, deriving a subjective measure of risk attitudes of consumers is a popular approach in research on consumers' intertemporal decisions (e.g., Barsky, Juster, Kimball, & Shapiro, 1997; Guiso & Paiella, 2000; and Guiso, Jappelli, & Pistaferri, 2002).

Due to the lack of survey data, we follow a statistical approach to construct a proxy for the risk attitude of managers. We follow Fisher and Hall (1969)[3] who suggest observed net returns data to estimate the risk premium for firms. As these authors point out, if the firm is following the optimal decision rule, then the risk premium of the firm can be measured by the moments of the distribution of net returns. After the risk premium of the firm is estimated, we can derive the measure of risk aversion for the managers of the firm based on the relation between the risk premium and the measure of risk aversion predicted by utility theory (e.g., Arrow, 1971).

Before deriving our empirical proxy for the risk attitude of managers, we briefly present the economic theory underlying this approach. The firm is maximizing the utility function $U(\pi + W)$, where π is earnings (a random variable) and W is net worth. Expanding $U(\pi + W)$ in a Taylor

[3] Also see Antle (1989).

series around the point $(\pi''+W)=E(\pi+W)$ gives:

$$U(\pi+W)=U(\pi''+W)+U'(\pi''+W)(\pi-\pi'')+\frac{U''}{2!}(\pi''+W)(\pi-\pi'')^2 + \frac{U'''}{3!}(\pi''+W)(\pi-\pi'')^3+\cdots. \tag{12}$$

Taking expected values and holding W and π'' constant,

$$E[U(\pi+W)]=U(\pi''+W)+\sigma_\pi^2\frac{U''}{2!}(\pi''+W)+\sigma_\pi^3\frac{U'''}{3!}(\pi''+W)+\cdots. \tag{13}$$

After rearranging terms, the difference between expected utility and utility of expected earnings is:

$$U(\pi''+W)-E[U(\pi+W)]=-\sigma_\pi^2\frac{U''}{2!}(\pi''+W)-\sigma_\pi^3\frac{U'''}{3!}(\pi''+W)+\cdots. \tag{14}$$

The above expression is the risk premium. It shows that the second, third and higher moments affect the magnitude of the risk premium. Since $U''<0$ for a concave utility function (a risk-averse agent), the risk premium is positively associated with larger variances of returns. However, since U''' could be positive, zero, or negative, the impact of the third moment on the risk premium is ambiguous. Higher moments add little information about the characteristics of the distribution and are often ignored (Fisher & Hall, 1969).

Expression (14) contains the relation between the risk premium and the measure of risk aversion. The left-hand side of (14) is the risk premium, on the right-hand side the second derivative of the utility function U'' reveals the risk attitude of the agent. Arrow (1971) illustrates the relation between the risk premium and the measure of risk aversion:

$$\text{risk premium}=\left(\frac{1}{2}\right)\sigma^2R_a+\text{terms of higher order}, \tag{15}$$

where σ^2 is the variance of a stochastic variable (e.g., net returns). R_a is the measure of absolute risk aversion. Therefore, if we know the risk premium of the firm and the volatility of net returns, it is possible to derive the measure of risk aversion for the managers of the firm.

According to Fisher and Hall (1969), if the firm is following the optimal decision rule, then the risk premium can be measured by moments of the distribution of net returns. We use historical data on net profits to construct the risk premium. We scale net profit by total assets, in order to eliminate size effects (also see Fisher & Hall, 1969). The distribution of the profit rate per firm, i.e., the variance and the skewness are computed over the past 5 annual observations.

Since the second and the third moments of the distribution of the profit rate are able to reflect the risk premium of the firm, we are especially interested in how much of realized net profits can be explained by the second and the third moments. To see that, we estimate the following equation for the profit rate:

$$\mathrm{PT}_t^R=\mathrm{PT}^*+\alpha_1\mathrm{SD}_t+\alpha_2\mathrm{SKEW}_t, \tag{16}$$

where PT_t^R is realized net profits (scaled by total assets) at time t. SD_t is the standard deviation of the profit rate at time t. SKEW_t is the third moment of the profit rate (skewness). We compute both the standard deviation and the skewness of the profit rate at time t by using the last 5 annual observations of the profit rate. PT^* is a constant, which reflects all influences on realized profits not encompassed by the standard deviation and skewness: the 'risk-adjusted' rate of return. The risk premium is the difference between realized profits and 'risk-adjusted' profits. Therefore, by estimating Eq. (16), we obtain 'risk-adjusted' profits (PT^*) for each firm. By assuming that the firm's 'risk-adjusted' profits (PT^*) are constant over the whole sample period, we construct a proxy for the risk premium as $\mathrm{RP}_t = (\mathrm{PT}_t^R - \mathrm{PT}^*)$.

Utility theory (see Eqs. (14) and (15)) suggests that we can derive a risk attitude parameter for managers by looking at how much the risk premium is attributed to the second moment of the distribution of profit. Therefore we estimate the following equation firm by firm:

$$\mathrm{RP}_t = \mathrm{RC} * \mathrm{SD}_t + \omega * \mathrm{SKEW}_t, \tag{17}$$

where the estimated coefficient for the standard deviation of profits (RC) reveals the measure of absolute risk-aversion of the managers of the firm. Table 1 presents the results of estimating the risk aversion coefficient (RC) (Eq. (17)) for all the firms in the sample. Among the initial 94 firms (see data description below), 68 firms are valid samples. For these firms, the second moment of the profit rate can significantly explain realized net profits, which indicates that risk attitude is important in determining the magnitude of the risk premium for these firms. Table 1 shows that some sample firms have a negatively significant risk coefficient (RC < 0), some others have a positively significant risk coefficient (RC > 0). According to utility theory, the positive risk coefficient (RC > 0) indicates that the managers of the firm are risk-averse. If the estimated risk coefficient is negative (RC < 0), then it suggests that the managers are risk-taking. Finding a non-significant parameter estimate RC indicates risk neutrality.

By estimating Eq. (17), we obtain a parameter that measures the degree of risk aversion of the managers of the firm, which we call the 'risk coefficient' (RC). Since the risk premium is proxied by the component of realized profits that is explained by the second and third moments of the distribution of profits, the estimated risk coefficient indicates how much of the risk premium can be attributed to the second moment of the distribution of profits. From utility theory (e.g., Arrow, 1971), a higher risk coefficient corresponds to a higher degree of risk aversion. We will use the estimated risk coefficient (RC) as the empirical proxy for the risk attitude of the managers of the firm in the remainder of this paper.

4. Data and construction of the uncertainty measure

4.1. Data description

We start with a stratified unbalanced panel of 94 Dutch non-financial firms listed at the Amsterdam Stock Exchange (AEX) during the period 1985–2000. We restrict the sample to 68 firms, whose risk attitude matters significantly in explaining realized profits (the estimated risk coefficient RC is statistically significant in estimating Eq. (17)). This implies that we exclude the 26 firms with insignificant estimates of the risk-attitude parameter RC, thereby ruling out risk-neutral firms. In order to construct the data on changes in tangible fixed assets (net investment) and the annual growth rate of sales, the first-year observation is lost for each firm. To construct the measure of demand uncertainty (see the explanations below), the first three observations are lost for each firm. This implies that the longest time series in the empirical investment model is 1988–2000.

The 68 valid sample firms are from 9 main industries, including construction, metals/machinery, chemical, textile, food, transportation, retail/wholesale, and business service/information. Table 2

Table 1
Estimating the risk attitude coefficient: $RP_t = RC^*SD_t + \omega^*SKEW_t$

Firm	RC	t-Statistic	R^2	Firm	RC	t-Statistic	R^2
Aaberts	−0.0566	−0.1548	0.0778	Internatio Muller	−0.2198	−0.5735	0.6206
Ahold	0.9639	3.2257	0.0468	KBB	1.8485	4.0979	0.2927
Ahrend	0.5008	1.1058	0.0380	Klene	0.0706	0.2859	0.3005
Akzo	−0.1804	−0.4365	0.0209	KLM	−1.3798	−3.1487	0.4285
Alanheri	−1.9578	−3.9281	0.2997	Krasnapolsky	2.7755	8.5862	0.5344
Atag	−2.8018	−29.0308	0.9894	Lander	−0.1557	−0.2586	0.3507
Athlon	−0.1161	−0.2408	0.0107	Macintosh	−0.0640	−0.2064	0.0003
Ballast	0.7081	4.2716	0.5141	Management share	−0.8175	−2.1361	0.4046
Batenburg	−0.3169	−0.6730	0.3053	Nagron	−0.8940	−4.7155	0.4289
Beers	−0.2390	−0.6951	0.0948	NBM	1.1892	3.6310	0.5483
Blydenstein	0.9108	6.1365	0.5752	Nedap	1.7594	4.6331	0.2393
Boer	−2.2658	−5.2906	0.5787	Nedcon	−1.7634	−6.1256	0.3651
Bolswessanen	2.0132	4.8794	0.3239	Nedlloyd	0.2053	1.4352	0.6269
Boskalis	−0.7348	−3.7682	0.4614	Nedschroef	0.1745	0.2798	0.0482
Burgman	−1.5155	−1.7604	0.4322	Neways	0.1194	0.5239	0.0826
Cate Ten	0.05231	0.1095	0.1341	NKF	0.0021	1.7798	0.3185
Cindu	2.5855	31.4980	0.9942	Norit	−1.6555	−5.5189	0.3066
Content	0.4086	2.7804	0.4846	Oce	0.2516	0.6631	0.2538
CSM	2.0278	5.1722	0.5879	Ommeren	2.9059	7.0579	0.6551
Delft Instruments	−1.2452	−3.1873	0.2970	Otra	−1.7749	−4.6891	0.6502
Dico	−3.4981	−19.7045	0.9219	PC Groep	−2.2783	−15.0152	0.8809
Dorp	−1.5795	−4.8288	0.4743	Pakhoed	0.3179	0.7483	0.1255
Draka	0.9919	2.8386	0.1484	Philips	2.1073	7.5946	0.7281
Drie Electronics	−1.2516	−4.7605	0.3337	Polygram	−2.9116	−9.3338	0.9198
DSM	−0.6375	−1.9612	0.0649	Polynorm	−0.1371	−0.3435	0.0905
Econosto	−2.0913	−7.1415	0.5086	Porceleyne	−2.2163	−5.7416	0.3483
Eriks	0.6854	1.3234	0.2730	Randstad	1.3179	4.3754	0.1366
Flexovit	−1.9903	5.5535	0.5388	Reesink	−1.4018	−8.7633	0.7553
Free Record	−0.6297	−2.3549	0.1812	Rood Testhouse	−0.3597	−0.0342	0.0415
Fugro	0.2208	0.4203	0.0086	Roto Smeets	−1.2746	−4.4554	0.4107
Gamma	−2.7925	−14.8293	0.8531	Samas	−0.6368	−1.5631	0.0419
Gelderse	−1.8928	−4.7454	0.5587	Schuitema	1.7391	5.1784	0.6350
Getronics	−1.5517	−7.6314	0.7853	Schuttersveld	−0.2617	−0.8578	0.0195
Geveke	−0.5579	−1.6367	0.1967	Simac	−1.1087	−2.6722	0.4489
Grolsch	1.0983	3.0002	0.1742	Sligro	0.0326	0.7577	0.7878
Grontmy	−0.7143	−2.2777	0.3439	Smit International	0.3913	2.5746	0.5104
Gti	−1.7930	−9.0192	0.8046	Sphinx	−3.1353	−15.9950	0.8576
Hagemeyer	1.1679	3.5355	0.4413	Stork	−2.9009	−11.6011	0.5592
Heineken	3.9838	13.9204	0.8102	Telegraaf	1.6243	5.8847	0.6541
Helvoet	−1.9057	−11.3242	0.7899	Ubbink	−1.2932	−2.0006	0.2618
Hes	−0.6466	−1.2488	0.1438	Unilever	−1.0842	−3.1222	0.5012
Heymans	−0.6797	−7.8462	0.8159	VNU	0.4461	1.7261	0.4379
Hoeks	−1.0979	−3.4393	0.1351	Volker	−0.3189	−1.7043	0.4808
Holland Colours	0.2880	2.7729	0.3721	Wegener	−0.4843	−1.7552	0.1963
Hollandse Beton	−2.5689	−15.0609	0.9541	Weweler	−1.3042	−5.0735	0.3271
Hoogovens	−1.4230	−3.9302	0.2096	Wolters	−0.4465	−1.3446	0.0813
IHC	0.2690	4.4174	0.4449				

Notes: Data sources: REACH, 94 Dutch listed nonfinancial firms in 1985–2000.

Table 2
Summary statistics

	Mean	Median	Std. Dev.	Skewness	Kurtosis	Obs.
I/K	0.0781	0.0685	0.0742	−0.8384	28.1526	739
SG	0.1071	0.0738	0.2217	4.1818	35.4453	739
CF/*K*	0.1073	0.1098	0.0569	−2.4243	20.7597	739
PT/*K*	0.0538	0.0569	0.0547	−2.6481	23.7436	739
UMS	0.1797	0.1312	0.2043	4.3936	29.5739	739
RP	−0.0211	−0.0116	0.0626	−3.0681	26.2908	739
RC	−0.4899	−0.8940	1.6992	0.5044	2.5139	739
RC_{dum}*UMS	0.0898	0.0264	0.1728	5.8414	53.9620	739
$(1 - RC_{dum})$*UMS	0.0898	0.0000	0.1675	3.9547	24.1826	739

Notes: (1) Data sources: REACH, 68 Dutch listed nonfinancial firms in 1985–2000. (2) Explanations of variables: *I/K*, gross investment scaled by total assets; SG, annual growth rate of sales; CF/*K*, cash flow scaled by total assets; PT/*K*, net profit scaled by total assets; UMS, measure of demand uncertainty; RP, risk premium; RC, risk coefficient; RC_{dum}, risk coefficient dummy, which is defined as one if RC is above the sample median, otherwise it is zero.

reports the summary statistics for the relevant variables. We also report the summary statistics for the constructed risk premium and the estimated risk coefficients. As shown in Table 2, for both the risk premium and the risk coefficient the mean and the median are negative. These statistics suggest that the sample firms on average show risk-taking behavior. Table 3 presents the correlation matrix for the variables used in the empirical analyses.

4.2. The measure of demand uncertainty

The investment model derived in Section 2 embeds a structural link between attitude towards risk and the effect of demand uncertainty on investment. Stochastic demand is found to be an important source of uncertainty faced by the firm (e.g., Guiso & Parigi, 1999), because it captures the overall external uncertainty surrounding the firm. To construct the measure of demand uncertainty, we first specify a forecasting equation for sales. In the forecasting equation, we assume that detrended sales follow an AR(1) process:

$$S_t = c_0 + c_1\mathrm{Trend} + c_2 S_{t-1} + \xi_t, \tag{18}$$

Table 3
Correlation matrix of the variables used in the estimations

	I/K	SG	CF/*K*	UMS	RC_{dum}*UMS	$(1 - RC_{dum})$*UMS
I/K	1.0000					
SG	0.3024	1.0000				
CF/*K*	0.0879	0.1712	1.0000			
UMS	−0.0174	0.0527	0.0522	1.0000		
RC_{dum}*UMS	−0.0147	−0.0251	0.0339	0.6168	1.0000	
$(1 - RC_{dum})$*UMS	−0.0061	0.0902	0.0287	0.5834	−0.2795	1.0000

Notes: (1) Data sources: REACH, 68 Dutch listed nonfinancial firms in 1985–2000. (2) Explanations of variables: *I/K*, gross investment scaled by total assets; SG, annual growth rate of sales; CF/*K*, cash flow scaled by total assets; PT/*K*, net profit scaled by total assets; UMS, measure of demand uncertainty; RP, risk premium; RC, risk coefficient; RC_{dum}, risk coefficient dummy, which is defined as one if RC is above the sample median, otherwise it is zero.

where c_0 is a constant, c_1 and c_2 are parameters, and ξ is an error term. We estimate Eq. (18) firm by firm. The estimation of the forecasting equation is based on the original data set (1985–2000). The residuals are saved for the period of 1986–2000. We then compute the rolling standard deviations of the residuals as the proxy for demand uncertainty.

This method of constructing the uncertainty measure and the similar forecasting equation have been adopted in the literature (e.g., Bo & Sterken, 2002; and Ghosal & Loungani, 2000). The measure of uncertainty constructed in this way emphasizes the unpredictable part of the stochastic process that governs demand. The rolling standard deviation of the residuals is based on all the past information of the residuals. More specifically, the rolling standard deviation of the residuals for the year 1988 is the standard deviation of the residuals computed over 1986, 1987, and 1988. For the year 1989, the rolling standard deviation of the residuals is the standard deviation of the residuals computed over 1986, 1987, 1988, and 1989, and so on. In estimating the investment equations, the standard deviation of the residuals is scaled by total assets to eliminate size effects. The scaled standard deviation is used as the measure of demand uncertainty and it is denoted by UMS_{it}.

5. Attitude towards risk and the investment-uncertainty relation

In this section we document the role of the risk attitude of managers in establishing the sign of the investment-uncertainty relation. We estimate a simple accelerator (sales growth) model including demand uncertainty. We first interact sales uncertainty with a dummy variable of the risk attitude of managers. To check for the robustness of the results, we further split the sample by the proxy for the risk attitude of managers based on whether the estimated risk coefficient is positive or negative.

5.1. Risk attitude dummy

Based on the estimated risk coefficient (RC), a dummy variable is constructed: we define the risk coefficient to be equal to unity if the value of the estimated risk coefficient is above the sample median and to zero otherwise. By interacting the risk coefficient dummy with the measure of demand uncertainty, we can check whether the effect of demand uncertainty differs due to the differences in the degree of risk aversion of managers. More specifically, we estimate the following investment equation:

$$\left(\frac{I}{K}\right)_{it} = f_i + f_t + \beta_1 \mathrm{SG}_{it} + \beta_2(\mathrm{UMS} * \mathrm{RC}_{\mathrm{dum}})_{it} + \beta_3(\mathrm{UMS} * (1 - \mathrm{RC}_{\mathrm{dum}}))_{it} + e_{it}, \tag{19}$$

where I_{it} is gross investment of firm i at time t, K_{it} are the beginning-of-period total assets of firm i at time t, f_i and f_t are fixed effect and time effect, respectively, SG is the annual growth rate of sales, representing the accelerator effect, UMS_{it} is the measure of demand uncertainty, $\mathrm{RC}_{\mathrm{dum}}$ denotes the risk coefficient dummy, and e_{it} is an error term.

The investment model is estimated by the system GMM estimator (Arellano & Bond, 1998). The system GMM estimation consists of a set of first-differenced equations and a set of levels equations. Moment conditions for equations in first differences are combined with moment conditions for equations in levels in order to compute the optimal weighting matrix providing consistent estimators. Time dummies are added in all models to correct for business cycle effects.

We also take into account the industry effect by adding industry dummies. In the system GMM estimation, the instruments for the first-difference equations are the lagged levels of the right-hand side variables.

In most of the estimations of this paper, we use the level observations lagged from $t-2$ to $t-5$ periods of the right-hand side variables as the instruments for the first-difference equations.[4] This decision is based on the failure of the Sargan test of over-identifying restrictions to reject the null hypothesis of instrument validity. In addition, we use the lagged first differences of the right-hand side variables as instruments for the levels equations. Since inference based on asymptotic standard errors for the one-step estimators is more reliable than that for the two-step estimators, we only report the results for the one-step estimators with robust test statistics (see Arellano & Bond, 1991; and Blundell & Bond, 1998).

Table 4 reports the GMM estimation results. Column 1 of Table 4 presents the estimated parameters and diagnostic checks of the benchmark model (19). The most important result is the difference between the estimated coefficients β_2 and β_3. We observe that the estimated coefficient for demand uncertainty for high-risk coefficient firms (UMS*RC_{dum}) is not significant. In contrast, the estimated coefficient for demand uncertainty for low-risk coefficient firms (UMS*$(1-RC_{dum})$) is highly significant with a positive sign. Since a higher risk coefficient corresponds to a higher degree of risk aversion, the insignificant coefficient of (UMS*RC_{dum}) suggests that managers with a higher degree of risk aversion are more cautious when responding to demand uncertainty: they simply do not increase the capital stock in responding to demand uncertainty loosely speaking. However, managers with a lower degree of risk aversion (UMS*$(1-RC_{dum})$) increase fixed investment expenditures in responding to high demand uncertainty.

In column 2 of Table 4 we control for investment persistence in order to check the robustness of the results. Specifically, we control the lagged one-period investment rate and lagged one-period sales in the estimations. In column 3 of Table 4 we further control for cash flow in the estimations, because cash flow is mostly found to be important in explaining investment. The results shown in columns 2 and 3 are quite consistent with those in column 1 of Table 4. The models in Table 4 meet all necessary tests. m_1 and m_2 are tests for first- and second-order serial correlation in the first-differenced residuals, asymptotically distributed as normal distribution under the null of no serial correlation. If the differenced residuals display significant negative first-order serial correlation (m_1 is significantly negative) and no second-order serial correlation (m_2 is not significant), there is no serial correlation in the residuals. The results presented in Table 4 show that the tests of serial correlation in the first-differenced residuals (m_1 and m_2) indicate that there is no serial correlation in the residuals. The Sargan (k) tests for the overidentifying restrictions (asymptotically distributed as $\chi^2(\mathrm{d}f=k)$ under the null of instrument validity). The Sargan test statistic supports the validity of the instruments used in the estimations.

5.2. Risk-averse versus risk-taking managers

To further check the robustness of the results, in this section we use the estimated risk coefficient (RC) to split the sample into two sub-groups, based on whether the estimated risk coefficient (RC) is positive or negative. Remember that firms used in estimating the empirical investment equation

[4] In the estimations shown in columns 1–3, the instruments for the first-difference equations vary a bit because the sub-sample of risk-averse firms is relatively small, for which use of the instruments uniformly lagged form $t-2$ to $t-5$ periods of the right-hand side variables sometimes results in unsatisfactory model performance. For example, in some cases serial correlation remains in the residuals.

Table 4
System GMM estimation results: risk attitude dummy $(I/K)_{it} = f_i + f_t + \beta_1 \mathrm{SG}_{it} + \beta_2(\mathrm{UMS{*}RC_{dum}})_{it} + \beta_3(\mathrm{UMS{*}}(1-\mathrm{RC_{dum}}))_{it} + e_{it}$

	1	2	3
$(I/K)_{t-1}$		0.0325 (0.6324)	0.0182 (0.3657)
SG_t	0.0596 (2.5625)	0.0653 (3.2359)	0.0744 (4.1488)
SG_{t-1}		0.0073 (0.3603)	0.0071 (0.3540)
$(\mathrm{CF}/K)_t$			0.0398 (0.8606)
$\mathrm{UMS}_t{*}\mathrm{RC_{dum}}$	0.0156 (0.6782)	0.0197 (0.6485)	0.0184 (0.6043)
$\mathrm{UMS}_t{*}(1-\mathrm{RC_{dum}})$	0.0872 (2.4354)	0.0832 (2.4659)	0.0754 (2.2346)
m_1	−2.919	−4.484	−4.360
m_2	−1.139	−0.573	−0.769
Sargan (k)	50.029 (144)	43.327 (191)	44.585 (239)
Instruments (dif.)	$\mathrm{SG}_{t-2\ldots t-5}$, $(\mathrm{UMS{*}RC_{dum}})_{t-2\ldots t-5}$, $(\mathrm{UMS{*}}(1-\mathrm{RC_{dum}}))_{t-2\ldots t-5}$	$(I/K)_{t-2\ldots t-5}$, $\mathrm{SG}_{t-2\ldots t-5}$, $(\mathrm{UMS{*}RC_{dum}})_{t-2\ldots t-5}$, $(\mathrm{UMS{*}}(1-\mathrm{RC_{dum}}))_{t-2\ldots t-5}$	$(I/K)_{t-2\ldots t-5}$, $\mathrm{SG}_{t-2\ldots t-5}$, $(\mathrm{CF}/K)_{t-2\ldots t-5}$, $(\mathrm{UMS{*}RC_{dum}})_{t-2\ldots t-5}$, $(\mathrm{UMS{*}}(1-\mathrm{RC_{dum}}))_{t-2\ldots t-5}$
Instruments (levels)	$\Delta\mathrm{SG}_{t-1}$, $\Delta(\mathrm{UMS{*}RC_{dum}})_{t-1}$, $\Delta(\mathrm{UMS{*}}(1-\mathrm{RC_{dum}}))_{t-1}$	$\Delta(I/K)_{t-1}$, $\Delta\mathrm{SG}_{t-1}$, $\Delta(\mathrm{UMS{*}RC_{dum}})_{t-1}$, $\Delta(\mathrm{UMS{*}}(1-\mathrm{RC_{dum}}))_{t-1}$	$\Delta(I/K)_{t-1}$, $\Delta\mathrm{SG}_{t-1}$, $\Delta(\mathrm{CF}/K)_{t-1}$, $\Delta(\mathrm{UMS{*}RC_{dum}})_{t-1}$, $\Delta(\mathrm{UMS{*}}(1-\mathrm{RC_{dum}}))_{t-1}$

Notes: (1) Data source: REACH. (2) The one-step GMM estimators are reported. (3) Heteroskedasticity consistent asymptotic t-statistics are in parentheses. (4) m_1 and m_2 are tests for first- and second-order serial correlation in the first-differenced residuals, asymptotically distributed as normal distribution under the null of no serial correlation. (5) Sargan (k): test of the overidentifying restrictions, asymptotically distributed as Chi-square (k) under the null of instrument validity. (6) Time effects are controlled in all estimations by adding time dummies. Industry dummies are also controlled. (7) Explanations of variables: see notes to Table 2.

Table 5
System GMM estimation results: whole sample $(I/K)_{it} = f_i + f_t + \theta_1 \text{SG}_{it} + \theta_2 \text{UMS}_{it} + \varepsilon_{it}$

	1	2	3
$(I/K)_{t-1}$		0.0286 (0.5612)	0.0082 (0.1691)
SG_t	0.0739 (2.9686)	0.0728 (3.3847)	0.0787 (4.1085)
SG_{t-1}		0.0042 (0.2009)	0.0032 (0.1567)
$(\text{CF}/K)_t$			0.0565 (1.0437)
UMS_t	0.0451 (2.0544)	0.0439 (1.9554)	0.0343 (1.4679)
m_1	−2.908	−4.438	−4.331
m_2	−1.238	−0.678	−0.964
Sargan (k)	40.881(96)	41.202(143)	42.054(191)
Instruments (dif.)	$\text{SG}_{t-2\ldots t-5}$, $\text{UMS}_{t-2\ldots t-5}$	$(I/K)_{t-2\ldots t-5}$, $\text{SG}_{t-2\ldots t-5}$, $\text{UMS}_{t-2\ldots t-5}$	$(I/K)_{t-2\ldots t-5}$, $\text{SG}_{t-2\ldots t-5}$, $(\text{CF}/K)_{t-2\ldots t-5}$, $\text{UMS}_{t-2\ldots t-5}$
Instruments (levels)	ΔSG_{t-1}, $\Delta(\text{UMS})_{t-1}$	$\Delta(I/K)_{t-1}$, ΔSG_{t-1}, $\Delta(\text{UMS})_{t-1}$	$\Delta(I/K)_{t-1}$, ΔSG_{t-1}, $\Delta(\text{CF}/K)_{t-1}$, $\Delta(\text{UMS})_{t-1}$

Notes: (1) Data source: REACH. (2) The one-step GMM estimators are reported. (3) Heteroskedasticity consistent asymptotic t-statistics are in parentheses. (4) m_1 and m_2 are tests for first- and second-order serial correlation in the first-differenced residuals, asymptotically distributed as normal distribution under the null of no serial correlation. (5) Sargan (k): test of the overidentifying restrictions, asymptotically distributed as Chi-square (k) under the null of instrument validity. (6) Time effects are controlled in all estimations by adding time dummies. Industry dummies are also controlled. (7) Explanations of variables: see notes to Table 2.

are firms for whom the estimated risk coefficient is significant in explaining the risk premium (Eq. (17)). For these firms, the estimated risk coefficient is either positive or negative. According to utility theory, the positive risk coefficient ($\text{RC} > 0$) indicates that the managers of the firm are risk-averse. If the estimated risk coefficient is negative ($\text{RC} < 0$), then it suggests that the managers are risk-taking. It is logical to assume that the effect of demand uncertainty on investment is highly likely to differ between risk-averse and risk-taking firms.

Therefore, we split the sample into two groups of firms, one with positive risk coefficients and the other with negative risk coefficients. Among 68 valid sample firms, 44 firms have negative risk coefficients and 24 firms have positive risk coefficients.[5] For both groups of firms we estimate the following investment equation:

$$\left(\frac{I}{K}\right)_{it} = f_i + f_t + \theta_1 \text{SG}_{it} + \theta_2 \text{UMS}_{it} + \varepsilon_{it}. \tag{20}$$

The aim of estimating the investment model (20) is to test whether the estimated effect of demand uncertainty, θ_2, differs between risk-averse and risk-taking firms. Before estimating Eq. (20) for sub-samples of firms, we present in Table 5 the results when all sample firms are pooled together in order to better understand the differences between the two sub-sample firms.

Column 1 of Table 5 displays the results of estimating the investment Eq. (20) for the whole valid sample. In column 2 we control investment persistence and in column 3 we further control for the cash-flow effect. The results in Table 5 suggest that when all firms are pooled together the estimated effect of demand uncertainty on investment is positive overall and it is significant in two out of three estimated equations. The estimated positive effect of demand uncertainty on

[5] Note that we exclude the risk-neutral cases: firms with an insignificant estimate of RC. On the one hand, inclusion of risk-neutral firms in our estimation sample makes the argument more pronounced, but on the other leads to a slight loss of generality.

Table 6
System GMM estimation results: risk-averse vs. risk-taking firms, $(I/K)_{it} = f_i + f_t + \theta_1 \mathrm{SG}_{it} + \theta_2 \mathrm{UMS}_{it} + \varepsilon_{it}$

	Risk-averse firms (RC > 0)			Risk-taking firms (RC < 0)		
	1	2	3	4	5	6
$(I/K)_{t-1}$		−0.0330 (−0.2869)	−0.0476 (−0.4574)		−0.0675 (1.7011)	0.0466 (1.2256)
SG_t	0.0669 (2.2635)	0.0599 (1.8804)	0.0705 (2.1217)	0.0859 (2.9998)	0.0787 (2.8741)	0.0655 (2.3909)
SG_{t-1}		0.0014 (0.0498)	0.0078 (0.2736)		0.0211 (0.7299)	0.0216 (0.7584)
$(\mathrm{CF}/K)_t$			−0.1996 (−0.9531)			0.0638 (1.2859)
UMS_t	−0.1809 (−1.8976)	−0.1643 (−1.8916)	−0.1286 (−1.8783)	0.0387 (2.0652)	0.0557 (2.6255)	0.0515 (2.2498)
m_1	−3.257	−3.247	−3.203	−1.989	−3.171	−2.983
m_2	−1.050	−1.083	−1.346	−1.257	−0.276	−0.663
Sargan (k)	0.506 (109)	0.000 (131)	167.505 (140)	17.290 (96)	17.708 (143)	18.223 (191)
Instruments (dif.)	$\mathrm{SG}_{t-2\ldots t-5}$, $\mathrm{UMS}_{t-2\ldots t-7}$	$(I/K)_{t-2\ldots t-3}$, $\mathrm{SG}_{t-2\ldots t-4}$, $\mathrm{UMS}_{t-2\ldots t-7}$	$(I/K)_{t-2\ldots t-3}$, $\mathrm{SG}_{t-2\ldots t-3}$, $(\mathrm{CF}/K)_{t-2\ldots t-3}$, $\mathrm{UMS}_{t-2\ldots t-5}$	$\mathrm{SG}_{t-2\ldots t-5}$, $\mathrm{UMS}_{t-2\ldots t-5}$	$(I/K)_{t-2\ldots t-5}$, $\mathrm{SG}_{t-2\ldots t-5}$, $\mathrm{UMS}_{t-2\ldots t-5}$	$(I/K)_{t-2\ldots t-5}$, $\mathrm{SG}_{t-2\ldots t-5}$, $(\mathrm{CF}/K)_{t-2\ldots t-5}$, $\mathrm{UMS}_{t-2\ldots t-5}$
Instruments (levels)	$\Delta\mathrm{SG}_{t-1}$, $\Delta(\mathrm{UMS})_{t-1}$	$\Delta(I/K)_{t-1}$, $\Delta\mathrm{SG}_{t-1}$, $\Delta(\mathrm{UMS})_{t-1}$	$\Delta(I/K)_{t-1}$, $\Delta\mathrm{SG}_{t-1}$, $\Delta(\mathrm{CF}/K)_{t-1}$, $\Delta(\mathrm{UMS})_{t-1}$	$\Delta\mathrm{SG}_{t-1}$, $\Delta(\mathrm{UMS})_{t-1}$	$\Delta(I/K)_{t-1}$, $\Delta\mathrm{SG}_{t-1}$, $\Delta(\mathrm{UMS})_{t-1}$	$\Delta(I/K)_{t-1}$, $\Delta\mathrm{SG}_{t-1}$, $\Delta(\mathrm{CF}/K)_{t-1}$, $\Delta(\mathrm{UMS})_{t-1}$

Notes: (1) Data source: REACH. (2) The one-step GMM estimators are reported. (3) Heteroskedasticity consistent asymptotic t-statistics are in parentheses. (4) m_1 and m_2 are tests for first- and second-order serial correlation in the first-differenced residuals, asymptotically distributed as normal distribution under the null of no serial correlation. (5) Sargan (k): test of the overidentifying restrictions, asymptotically distributed as Chi-square (k) under the null of instrument validity. (6) Time effects are controlled in all estimations. Industry dummies are also controlled. (7) Explanations of variables: see notes to Table 2.

investment may be explained by the notion that more than half of the sample firms have a negative risk coefficient (see Table 1). This suggests that the sample firms on average show risk-taking behavior when adjusting investment in responding to demand uncertainty. It is more interesting to further check whether the effect of demand uncertainty differs between risk-averse and risk-taking firms.

We estimate the same investment equations shown in Table 5 for risk-averse and risk-taking firms, respectively. Table 6 reports the estimation results. The most important result emerging from Table 6 concerns the difference in the estimated effect of demand uncertainty on investment, θ_2, between risk-averse and risk-taking firms. In all models, the estimated coefficient for the measure of demand uncertainty is significant with a negative sign for risk-averse firms, while it is significant with a positive sign for risk-taking firms. Consistent with the predictions of theoretical models (e.g., Nickell, 1978), our results show that risk aversion discourages firm investment under demand uncertainty, while risk-taking firms increase investment expenditures with higher demand uncertainty. The evidence clearly suggests that the risk attitude of managers is indeed important in affecting how firm investment responds to demand uncertainty.

6. Summary and conclusions

We argue that the risk attitude of managers is a heavily neglected determinant of the sign of the investment-uncertainty relation. The obvious reason for this omission is the lack of an empirical proxy for the risk attitude of managers. We try to fill this gap in this paper and show that simply assuming risk neutrality might blur econometric estimates of the sign of the investment-uncertainty relationship.

Following the idea put forward by Fisher and Hall (1969), we compute the second and the third moments of the distribution of net profits and use these distribution variables to explain realized net profits.[6] The part of realized net profits that can be explained by these distribution variables is defined as the risk premium of the firm. Since there is a theoretical connection between risk premium and the measure of risk aversion, we derive an empirical proxy for the risk attitude of managers by looking at how much the risk premium of the firm can be explained by the second moment of the distribution of net profits. The reason is that only the second moment is relevant to measuring the degree of risk aversion, according to utility theory (e.g., Arrow, 1971).

We test whether the proxy for the risk attitude of managers has an impact on the effect of demand uncertainty on fixed investment for an unbalanced panel of Dutch listed non-financial firms in the period of 1985–2000. The results show that in general a low degree of risk aversion is associated with a positive effect of demand uncertainty on fixed investment. More specifically, we obtain evidence that risk-averse firms respond to demand uncertainty by cutting investment, while the investment undertaken by risk-taking firms responds to demand uncertainty positively. These results are in line with Nickell (1978), who concludes that when demand is uncertain, risk-averse behavior is bound to lower capacity levels and the optimal capacity level is a declining function of the degree of risk aversion.

In sum, the evidence of this paper suggests that the risk attitude of managers is indeed important in influencing how firm investment responds to demand uncertainty, which implies that the risk attitude of managers might be a heavily neglected driving determinant of the often reported negative sign of the investment-uncertainty relation in the empirical literature. Our results suggest

[6] Also see Antle (1989).

that the assumption of risk neutrality does not apply to fixed-investment decision makers. This finding puts in question the results by other empirical studies that assume risk neutrality in estimating the sign of the investment-uncertainty relationship.[7] An issue for future research is the exact identification of the different channels through which different types of uncertainty affect investment.

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[7] See Lensink et al. (2001) for an extensive overview.